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Why do students struggle to understand composition functions? Analysis of learning obstacles in vocational education

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Abstract
Difficulties in understanding abstract mathematical concepts, particularly functions and function composition, are still commonly experienced by students, especially those in Vocational High Schools (SMKs). This study aimed to identify the learning obstacles experienced by eleventh-grade Vocational High School (SMK) students in learning functions and function composition. This study employed a qualitative descriptive approach as the initial stage of Didactical Design Research (DDR). Data were collected through diagnostic tests, semi-structured interviews, and documentation to identify learning obstacles related to function composition. The results indicate that students experienced various learning obstacles. They had difficulty understanding the concepts of functions and function composition, as reflected in their inability to distinguish between the two concepts and their dependence on examples provided by teachers, indicating epistemological obstacles. In addition, students experienced difficulty performing substitutions, determining the order of function composition, and applying solution procedures systematically, indicating instrumental ontogenic obstacles. The interview results also revealed that learning practices oriented toward memorization contributed to these difficulties, indicating didactical obstacles. Therefore, students' difficulties in learning function composition were influenced by epistemological, instrumental ontogenic, and didactical obstacles. These findings provide a basis for developing more effective learning designs that emphasize conceptual understanding.

Keywords: Compositional function, Didactical obstacle, Epistemological obstacle, Learning obstacle, Ontogenic obstacle

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Introduction

Education is an effort that is deliberately and systematically designed to create learning activities that allow students to be actively involved in developing their potential, including cognitive, affective, and psychomotor aspects (Rahman et al., 2022). One of the subjects that plays an important role in developing logical, analytical, and structured thinking skills is mathematics. However, in practice, there are still many students who face difficulties in understanding mathematical concepts that tend to be abstract (Sari et al., 2020). This condition is an important question, especially in the material of the composition function: why do students still have difficulty in understanding the concept?

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Mathematics as an abstract science requires a strong conceptual understanding, especially in algebraic material that forms the basis for advanced concepts such as functions and calculus (Sari et al., 2020). One of the materials that often causes difficulties is the composition function, which requires students to understand the relationship between functions and perform operations in sequence (Saputri, 2025). Furthermore, many students have difficulty in determining the results of the composition of functions, performing substitutions, and distinguishing between function operations and ordinary algebraic operations (Saputri, 2025). This shows that the difficulties students experience are not only related to the procedure, but also include a deeper conceptual understanding.

The difficulties experienced by students may be related to discrepancies between their concept image and concept definition. Tall dan Vinner (1981) explain that concept image refers to the total cognitive structure associated with a concept, whereas concept definition refers to its formal mathematical definition. When students' concept images do not align with formal definitions, misconceptions and errors may arise, particularly in abstract topics such as composition functions.

Students' learning difficulties in the topic of composition functions can be analyzed through the perspective of learning obstacles. Brousseau (2002) classifies learning obstacles into epistemological, ontogenic, and didactical obstacles, which may hinder students' understanding of mathematical concepts. This framework was further developed in mathematics education research (Hendriyanto et al., 2024; Suryadi, 2018). In this study, epistemological obstacles refer to barriers arising from the limited applicability of students' knowledge in different mathematical contexts. Ontogenic obstacles refer to barriers related to students' cognitive readiness and developmental characteristics. Meanwhile, didactical obstacles refer to barriers caused by instructional factors, such as teaching approaches, learning materials, and classroom learning situations (Herman et al., 2022).

However, previous studies have generally been limited to identifying learning difficulties in a broad sense or have focused on only one type of learning obstacle. In addition, studies specifically examining learning obstacles in the topic of composition functions within the context of Vocational High Schools (SMK) remain relatively limited. In fact, the characteristics of SMK students, who tend to prefer contextual and applicative learning, may give rise to different forms of learning obstacles (Adnyana et al., 2021). This condition indicates a research gap that has not been widely explored.

On the other hand, the teaching of composition functions in SMK is still dominated by procedural approaches and memorization. As a result, students experience difficulties not only in solving problems but also in developing a deep understanding of the concepts (Aprilianti, 2022; Konnova et al., 2019; Pramesti & Ferdianto, 2021). Therefore, a study that is able to comprehensively reveal students' learning obstacles is needed.

Based on these considerations, this study offers novelty by providing an integrated analysis of three types of learning obstacles: epistemological, ontogenic, and didactical in the topic of composition functions within the context of eleventh-grade SMK students. This study also relates learning obstacles to students' characteristics and the instructional practices implemented, with the aim of contributing to the development of more effective and contextual learning designs.

Methods

This study employed a qualitative descriptive approach to identify learning obstacles experienced by students in understanding composition functions. The study was conducted as the initial stage of Didactical Design Research (DDR), which focuses on identifying learning obstacles as a basis for developing an appropriate didactical design (Suryadi, 2013). Therefore, this research concentrated on exploring epistemological, ontogenic, and didactical obstacles through diagnostic tests and interviews.

This study was conducted at a Vocational High School (SMK) during the even semester of the 2025/2026 academic year. The participants were grade XI students who had previously studied the topic of function composition. Subject selection was carried out using purposive sampling, considering variations in students' ability levels (high, medium, and low) in order to obtain a more comprehensive understanding of different forms of learning obstacles that contribute to learning difficulties. From a class consisting of 28 students, several were chosen as the primary subjects for further analysis

As the initial stage of DDR, the research procedure consisted of identifying potential learning obstacles through literature review, administering diagnostic tests, conducting semi-structured interviews, and analyzing the findings to classify the identified learning obstacles (Brousseau, 2002; Suryadi, 2018). The research procedure consisted of four stages. First, a literature review and a preliminary analysis of composition function materials were conducted to identify potential learning obstacles. Next, diagnostic tests were administered to determine students' difficulties in understanding composition functions. Semi-structured interviews were then conducted with selected students and teachers to explore the causes of the identified difficulties. Finally, the findings were analyzed and classified into epistemological, ontogenic, and didactical obstacles.

The data in this study were collected through diagnostic tests, semi-structured interviews, and documentation (Creswell, 2018; Flick, 2018). The diagnostic tests were used to identify the different types of difficulties students face in understanding function concepts as well as in solving problems involving function composition. The test consisted of open-ended questions designed to assess students' ability to define functions, determine function composition, perform substitutions, and solve contextual problems (Pramesti & Ferdianto, 2021). Furthermore, semi-structured interviews were conducted to explore in greater depth the reasons underlying students' errors, thereby enabling the identification of the types of learning obstacles experienced by students (Creswell, 2018). Documentation in the form of students' written responses and interview recordings was used as supporting data to support data analysis and ensure the credibility of the findings (Morgan, 2024; Stahl & King, 2020).

The instruments used in this study include the researcher as the primary instrument, supported by diagnostic tests and interview guidelines. These instruments were developed to assess students' understanding of function concepts and function composition. Prior to their implementation, the test items administered to students were validated by two experts in mathematics education. The validation results showed that there was an improvement in the distribution of the cognitive level of the questions, namely the reduction of questions at the C2 level (understanding) and the addition of questions at the C4 level (analysis), as well as adjustments to the context of the questions to be clearer and more relevant. The interview guidelines are also adjusted to the question items to ensure the depth of data exploration.

Data analysis in this study was carried out with a qualitative approach that included the stages of data reduction, data presentation, and conclusion drawn. At the data reduction stage, student answers and interview results are classified based on the type of error that arises. Furthermore, the data were analyzed to identify the causes of learning difficulties and were categorized into three types of learning obstacles: epistemological obstacles, ontogenic obstacles (obstacles related to students' readiness or ability, particularly in instrumental aspects), and didactical obstacles (obstacles arising from the learning process). To clarify the analysis process, the categories of student errors are formulated as shown in Table 1.

Table 1. Categories of Student Errors and Types of Learning Obstacles

No Question	Student Difficulties Indicators	Types of Learning Obstacles
1	Unable to explain the meaning of the function correctly The example given does not fit the definition	Epistemological Obstacles
2	Unable to write down the form of the composition correctly Reasons for not complying with the concept of function composition	Ontogenic conceptual obstacles
3	Not writing the composition form correctly Mistakes in substitution Algebraic procedure errors Improper finish	Instrumental Ontogenic Obstacles
4	Unable to determine the composition correctly Inappropriate conclusion	Epistomological obstacles
5	Unable to model story problems into the form of functions Errors in determining the order of the composition Unable to explain the influence of process sequence	Didactical obstacles

The data is then presented in the form of narrative descriptions and tables for easy interpretation. The final stage is the drawing of conclusions by identifying the most dominant types of learning obstacles and their relationships as the main causes of students' difficulties in understanding the function of composition.

To ensure the validity of the data, this study applies a method triangulation technique, namely by comparing and confirming data obtained from diagnostic tests, interviews, and documentation (Fadli, 2021; Sugiyono, 2022). This triangulation technique is used to increase the credibility of the data so that the results of the research can represent real conditions in the field more accurately (Creswell, 2018; Morgan, 2024; Schlunegger et al., 2024).

Results

Based on the test results given to 28 students, there were five questions used to identify learning obstacles in the composition function material. However, in this article, the discussion is focused on questions number 1 and number 4 because both questions are considered to represent indicators of understanding the basic concepts of function and students' ability to complete composition functions.

Question 1. Explain in your own words what a function is and provide an example of a function.

Table 2. Student Answer Results to Question Number 1

Answer Categories	Number of Students
Correctly answer function definitions and examples	15
Answer a function definition, but without an example	9
Misanswer definitions and examples	1
Misdefined, but the example is true	3
Not answering	0

As shown in Table 2, most students were able to understand the concept of a function. A total of 15 students correctly explained the definition of a function and provided appropriate examples, such as $f(x) = 2x + 2$. More detailed examples of students' responses are discussed in the following section. However, nine students were only able to explain the definition without providing an example, while several others still demonstrated misconceptions regarding the concept of a function.

Question 4. Given $f(x) = 2x + 1$ dan $g(x) = x^2$. (a) Find $(fog)(x)$ and $(gof)(x)$. (b) Compare the two results. Are they the same or different? Explain your reasoning.

Table 1. Student Answer Results to Question Number 4

Answer Categories	Number of Students
Determine $(\boldsymbol{fog})(\boldsymbol{x})$ and compare correctly$(\boldsymbol{gof})(\boldsymbol{x})$	15
Determine both functions, but the end result is wrong, the comparison is correct	2
Define the two functions, but don't compare them	4
Unable to determine the two functions and compare	7

Table 3 shows that students' ability to solve composition function problems is still diverse. A total of 15 students were able to answer correctly, but there were still students who experienced difficulties, both in determining the results of the composition of the function and in comparing the two functions given.

Based on the data in Table 2 and Table 3, it can be seen that even though some students have been able to solve the problem correctly, there are still a number of students who have difficulty in understanding the concept of function and in working on problems related to the composition function. The diagnostic test consisted of items assessing students' conceptual understanding and procedural skills related to composition functions, including explaining function concepts, writing composition forms, performing substitutions, determining composition results, and modeling contextual problems. These indicators were used to identify the characteristics of epistemological and instrumental ontogenic obstacles, as reflected in students' responses.

Discussion

Based on the results of the study, it is known that students still face various learning obstacles in understanding the material function of composition. These findings are in line with the view Guy Brousseau which states that learning barriers are common in the mathematics learning process, especially in materials that have a high level of abstraction.

Question 1

Based on students' responses to Question 1, their understanding of the concept of a function was generally good, as most students were able to explain the definition of a function correctly and provide appropriate examples. However, some students still demonstrated incomplete understanding, as indicated by their inability to provide appropriate examples and their misconceptions regarding the concept of a function. These findings suggest the presence of epistemological obstacles related to students' conceptual understanding of functions.

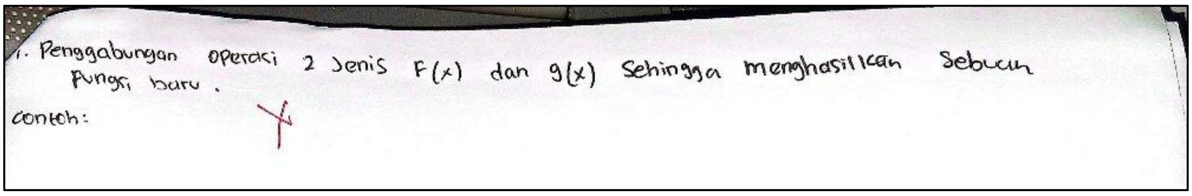

Figure 1. Answer Students who answer the wrong definition of the function and do not answer the example

Translation of the student's answer:
The combination of two functions $f(x)$ and $g(x)$ resulting in a new function.
Example:

Based on Figure 1, students write that a function is "a combination of two types of operations $f(x)$ $g(x)$ and thus produces a new function". The answer shows that students understand functions as the result of the merger of two functions, which actually leads more to the concept of function composition rather than the definition of function in general.

Students' mistakes show the inability to distinguish the concepts of function and function of composition as well as limitations in providing appropriate examples, so that understanding is still not thorough. This indicates the existence of epistemological obstacle, which is an obstacle due to limited understanding of concepts, where students tend to associate functions only in certain contexts so as to cause misconceptions. These findings are in line with previous research that has stated that conceptual errors in mathematics often arise as a result of limited understanding and are bound to specific contexts (Brousseau, 2002; Tall & Vinner, 1981). This analysis is based on students' written answers that have sufficiently shown conceptual errors.

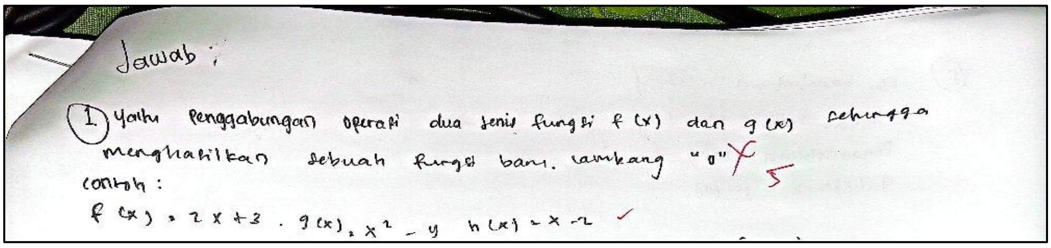

Figure 2. The student's answer that incorrectly answers the definition of the function but the example is correct

Translation of the student's answer:
The combination of two functions $f(x)$ and $g(x)$ so that it produces a new function.
Symbolize "o ".
Example: $f(x) = 2x + 3$, $g(x) = x^2 - y$, $h(x) = x - 2$

Based on Figure 2, students define a function as "the merger of the operations of two types of functions $f(x)$ and $g(x)$ thus produce a new function. Symbolize "o " which indicates that students are confusing the concept of function with the function of composition. Nevertheless, the examples given by the students are appropriate in the form of functions $f(x)$, $g(x)$ and $h(x)$.

This shows that students' mistakes lie in understanding the basic concept of function, not in the ability to give examples, so that students are not able to distinguish precisely between the concept of function and the function of composition. This is in line with research findings that errors in mathematics often stem from a weak understanding of basic concepts, not just procedural errors (Ario & Jupri, 2025; Ruli et al., 2025).

Thus, students experience epistemological obstacles, which are learning obstacles that arise due to limitations in understanding concepts. This is also reinforced by didactic theory which states that the knowledge that students have built up in a given context has the potential to become an obstacle when applied to different situations (Ario & Jupri, 2025; Marlinda & Effendi, 2024; Munawwaroh et al., 2025). This analysis is based on written answers because students are not interviewed.

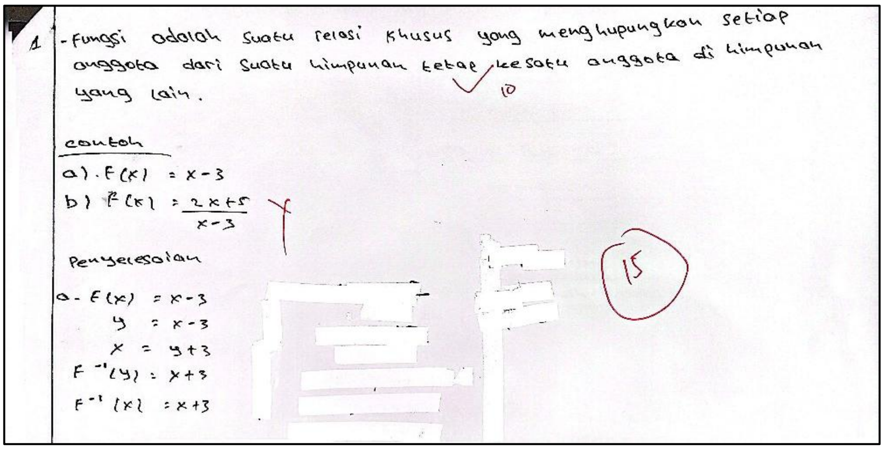

Figure 3. Student's response to Question 1: Defining a function without providing an example.

Translation of the student's answer:

A function is a special relation that maps each element of a set to exactly one element of another set.

Example: $a)\ f(x) = x - 3,\ b)\ f(x) = \frac{2x+5}{x-3}$

Solution:

$f(x) = x - 3$

$y = x - 3$

$x = y + 3$

$f^{-1}(y) = y + 3$

$f^{-1}(x) = x + 3$

In Figure 3, students are able to provide examples of functions correctly, but still show doubts in understanding the concept of function as a whole. This can be seen from the students' answers which are still simple and have not been accompanied by a complete and adequate explanation.

The findings were also strengthened through the results of interviews conducted with students as follows:

Researcher : What difficulties did you have when asked to give an example of a function?

Student : It was a little difficult because I was asked to give examples of functions, but I had notes and examples of questions that the teacher had previously explained.

Based on this, it can be seen that students still tend to depend on the examples given by the teacher and are not fully able to understand the concept of function independently. Therefore, students experience epistemological obstacles, which are obstacles that arise due to limitations in understanding concepts.

The results of the analysis of three variations of students' answers to question number 1 show that students' understanding of the concept of function is still uneven. Some students make mistakes in defining functions by confusing the concept of functions and compositional functions, while others are able to give examples of functions correctly but still misunderstand the definition. In addition, there are students who have answered correctly, but still show dependence on the examples given by the teacher.

These findings show that students' understanding of the concept of function is still partial and limited to certain contexts (Pratiwi et al., 2024). Therefore, in general, it can be concluded that students experience *epistemological obstacle*, which is an obstacle that occurs due to the incomplete understanding of the concept of function. (Aini et al., 2023). This condition is in line with research findings that show that epistemological barriers occur when students' understanding is still limited to certain situations and cannot be applied flexibly to different contexts (Munawwaroh et al., 2025).

In addition to understanding the concept of function, students' difficulties are also seen in the ability to complete the composition function shown in question number 4, namely: Known and Questions: a. Determine and b. Are the two results the same or different? This question requires students to determine and compare the two outcomes. $f(x) = 2x + 1 g(x) = x^2. (fog)(x)(gof)(x)(fog)(x)(gof)(x)$.

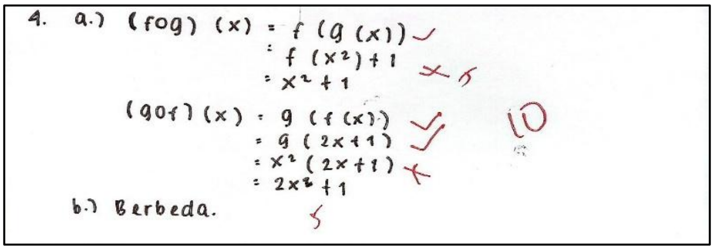

Figure 4. Student Answer Determine both functions, but the end result is wrong, the comparison is correct

In Figure 4, the students have understood the general form of the composition function correctly, i.e. $(fog)(x) = f(g(x))$and $(gof)(x) = g(f(x))$. However, students make mistakes in the process of substitution and simplification resulting in incorrect final answers.

This shows that students are still experiencing difficulties in implementing procedures or completion steps appropriately. Thus, it can be concluded that students experience ontogenic obstacles instrumental, which are obstacles related to the ability to use mathematical solving procedures or techniques. This analysis is based on written answers because students are not interviewed.

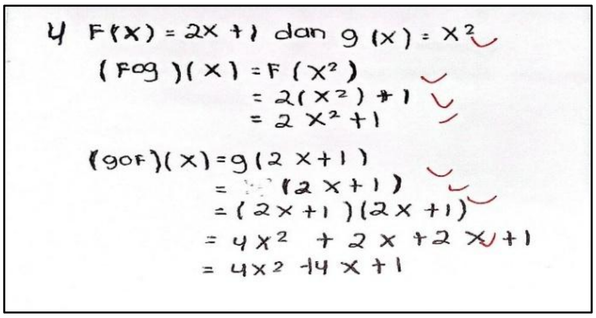

Figure 5. Define the two functions, but don't compare them

In Figure 5, students have been able to determine $(fog)(x)$ and $(gof)(x)$ correctly and show systematic completion steps. However, students did not answer the part of the question that asked to compare the two results.

This shows that students have difficulty in solving the problem completely according to the demands of the problem. Students tend to stop at the calculation stage without proceeding to the interpretation stage or drawing conclusions. Thus, students experience Ontogenic Obstacles instrumental, which is an obstacle related to the skill of completing the procedure completely and systematically (Ario & Jupri, 2025; Hidayati & Juandi, 2025; Pratiwi et al., 2024). This analysis is based on written answers because students are not interviewed.

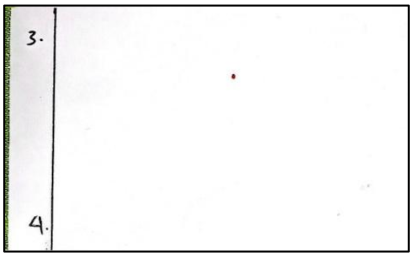

Figure 6. Unable to determine the two functions and compare

In Figure 6, it can be seen that students do not write down the answers to the questions given. This condition shows that students are unable to start the completion process or have not understood the steps needed to solve the composition function problem. These findings are reinforced by the following interview results:

Researcher : Why don't you answer question number 4? Is there a part of the calculation that makes you doubtful?
Student : Because I didn't understand how to answer the question, I forgot how to do it.
Researcher : How do you remember the order of the compositional functions that should be worked on first?
Student : Work on the one close to x.

Based on these results, it can be seen that students have not understood the procedure for solving the composition function and rely only on improper rules ("those close to x"). This indicates that students have difficulty remembering and applying the completion steps appropriately. Thus, students experience ontogenic obstacles instrumental, which are obstacles related to skills in using mathematical completion procedures or steps.

The findings regarding students' difficulties in understanding the concept of function and composition function were also supported by the results of interviews with teachers. The following is an excerpt of the interview.

Researcher : How do you assess students' understanding of the basic concept of function?
Teacher : The assessment of students' understanding of the basic concept of function is carried out thoroughly, focusing not only on the final result but also on the student's thought process. Teachers use diagnostic questions, questions and answers, and ask students to explain concepts in their own language.

Based on these quotes, teachers have tried to assess students' comprehensiveness. However, in practice, there are still difficulties experienced by students, as expressed in the following quote.

Researcher : Do you think students have difficulty distinguishing between two forms of function?
Teacher : Many students memorize the form of the function without understanding its characteristics, so when the form of the question is slightly different, they become confused.

The quote indicates that students' understanding of the concept of function is not deep, but is still limited to memorizing its form. This can also be seen in the difficulties of students in the procedural aspect, as expressed below.

Researcher : How are students' ability to determine the value of the function systematically?
Teacher : Some students are capable, but there are still those who are less careful in substitution and calculation.

In addition, in the composition function material, students' difficulties also appear in determining the order of functions.

Researcher : How are students able to calculate the composition of functions?
Teacher : There are still those who have difficulty in determining the sequence of functions and performing algebraic operations correctly.

Based on the transcript of the interview with the teacher, it can be seen that the students' difficulties in understanding the functional and functional materials of the composition lie not only in the final result, but also in the thought process that has not been optimal. Students tend to memorize the form of the function without understanding the basic concept, so they experience confusion when faced with different forms of problems. This condition shows the existence of epistemological obstacles, which are obstacles caused by limited understanding of concepts.

In addition, students also experience difficulties in carrying out the substitution process, determining the order in the composition function, and completing algebraic operations correctly. This indicates that students' procedural skills are still not developed optimally. These difficulties are included in the Ontogenic Obstacle (instrumental), i.e. obstacles related to students' skills in applying mathematical completion procedures or steps (Hidayati & Juandi, 2025; Riastuti et al., 2023).

On the other hand, students' dependence on the examples provided by teachers shows that the learning process still tends to emphasize procedural aspects. Students become difficult when faced with a problem that has a slightly different form from the example that has been given before. This condition indicates the existence of a didactical obstacle, which is an obstacle that arises due to a learning strategy that is not fully able to encourage in-depth understanding of concepts.

Conclusion

Based on the results of the research and discussions, it can be concluded that grade XI students of SMK still experience various learning obstacles in understanding functions and composition functions. Students tend to confuse the concepts of function and composition function and rely on examples provided by the teacher, indicating epistemological obstacles related to limited conceptual understanding.

Students also encounter difficulties in solving composition function problems, particularly in substitution, determining the order of functions, and completing solutions systematically. Some students are even unable to begin the solution process. These findings indicate the presence of instrumental ontogenic obstacles related to students' procedural skills. In addition, interview results reveal that students tend to memorize rather than understand concepts, which reflects didactical obstacles arising from instructional practices that do not yet emphasize conceptual understanding.

These findings imply the need for instructional improvements that focus more on strengthening conceptual understanding rather than procedural memorization. Teachers are encouraged to design more meaningful, contextual, and student-centered learning activities, as well as provide varied problem types to train students' understanding. Future research is recommended to develop and implement didactical designs that specifically address these learning obstacles in order to improve students' understanding of composition functions.

Declarations

Author Contribution	:	DS: Conceptualization, Writing - Original Draft, Editing and Visualization. RW: Writing - Review & Editing, Formal Analysis, and Methodology. DA: Validation and Supervision. N: Validation and Supervision.
Funding Statement	:	No funding.
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